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(54) **DEVELOPING DEVICE AND IMAGE FORMING APPARATUS INCLUDING THE SAME**

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G03G 15/08 (2006.01)

(52) **U.S. Cl.**
CPC ***G03G 15/0808*** (2013.01)

(58) **Field of Classification Search**
None
See application file for complete search history.

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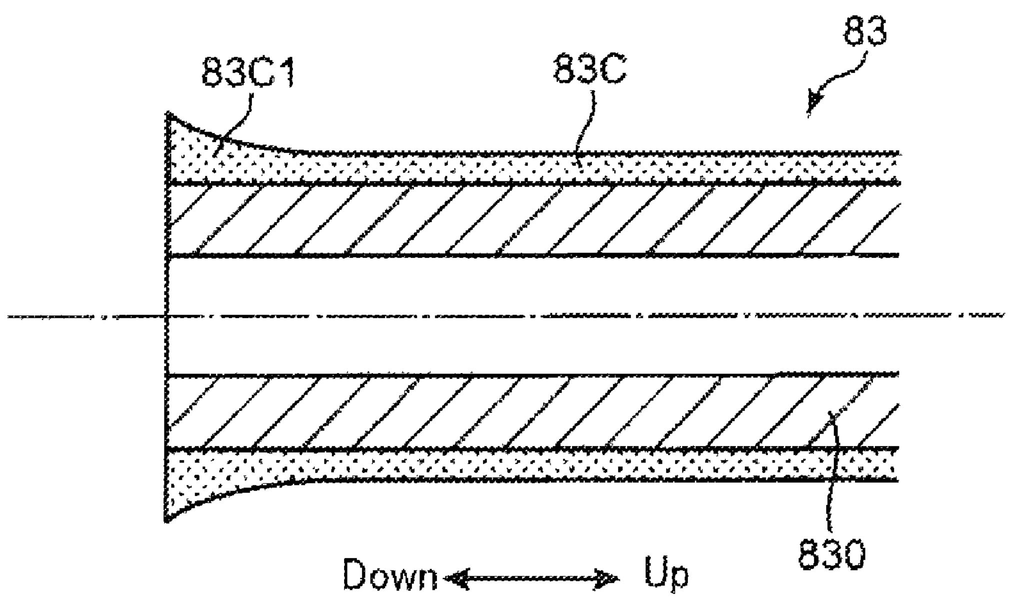
(57) **ABSTRACT**

A developing device includes a housing, a development roller, and a roller gear. The roller gear is disposed at one axial end of the development roller and transmits a rotational drive force to the development roller. The development roller includes a sleeve and a coating layer. The coating layer is formed by dipping the sleeve in a dipping bath with the sleeve directed axially vertically. The development roller is mounted to the housing such that a lower axial end of the development roller at the time of the dipping is an opposite axial end to the one axial end at which the roller gear is disposed.

6 Claims, 5 Drawing Sheets



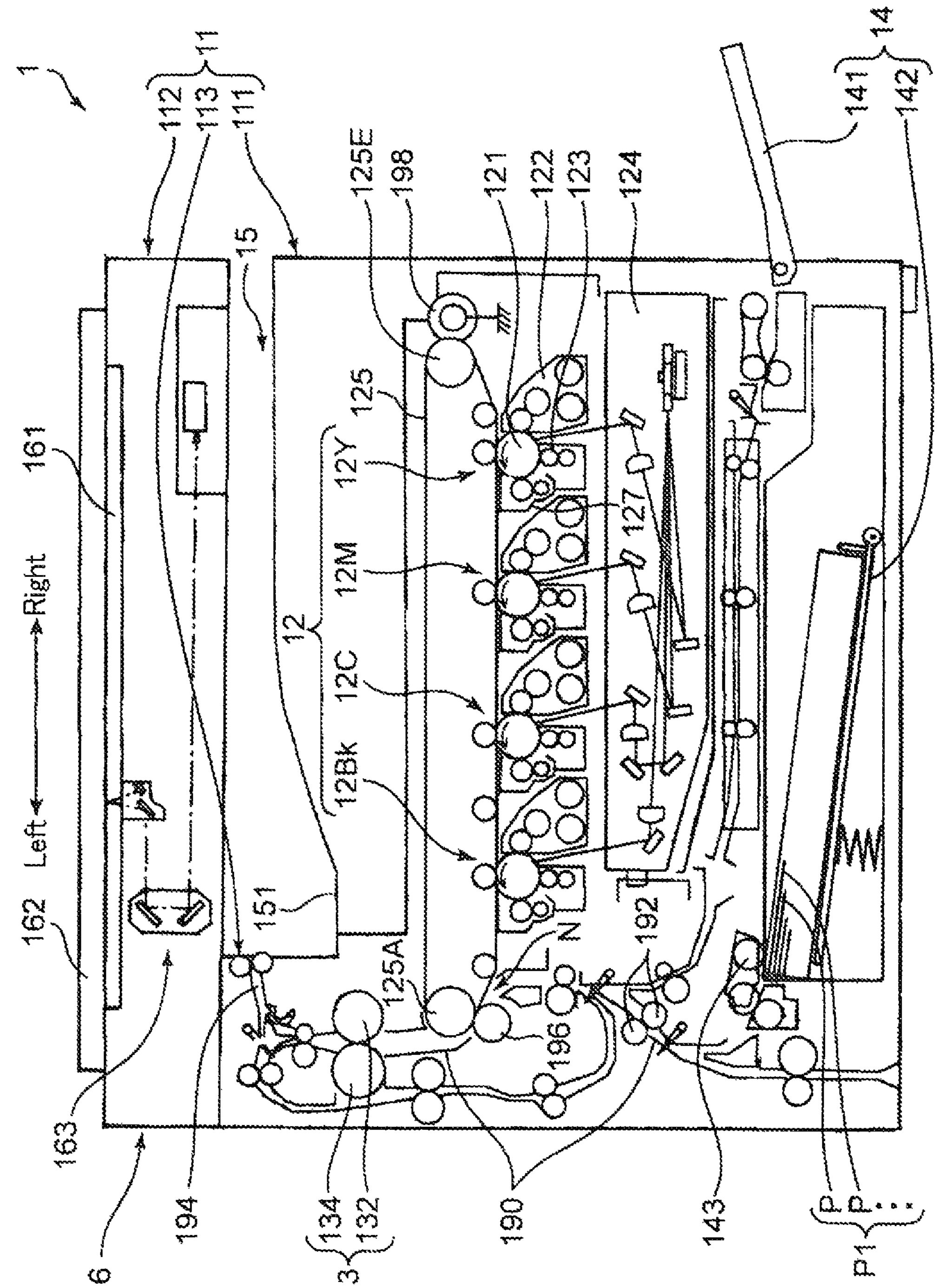

1
11
112
113
111
14
141
142
15
125E
198
121
122
123
124
161
125
12Y
127
Right
12M
12
12C
Left
12Bk
162
151
192
N
125A
196
163
16
194
134
132
13
190
143
P
P
P1

FIG. 1

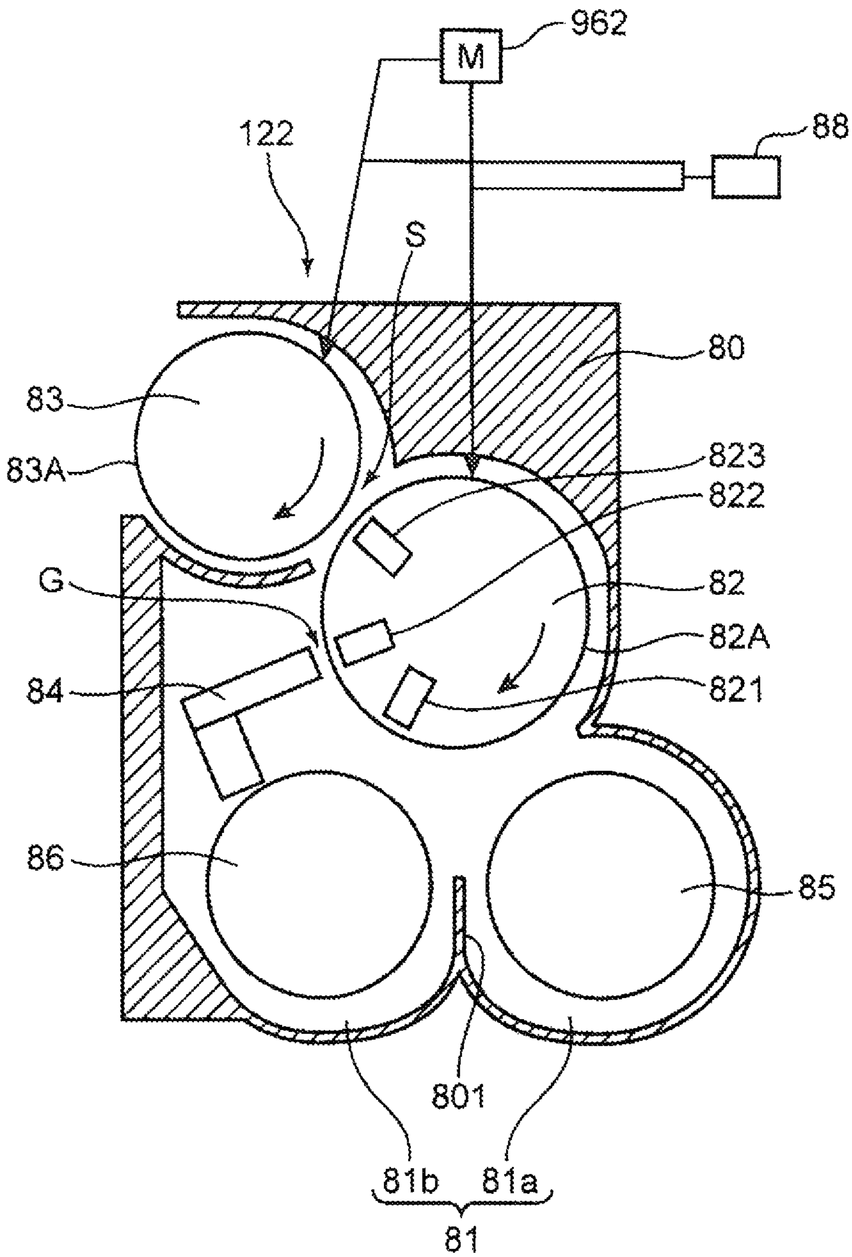


FIG. 2

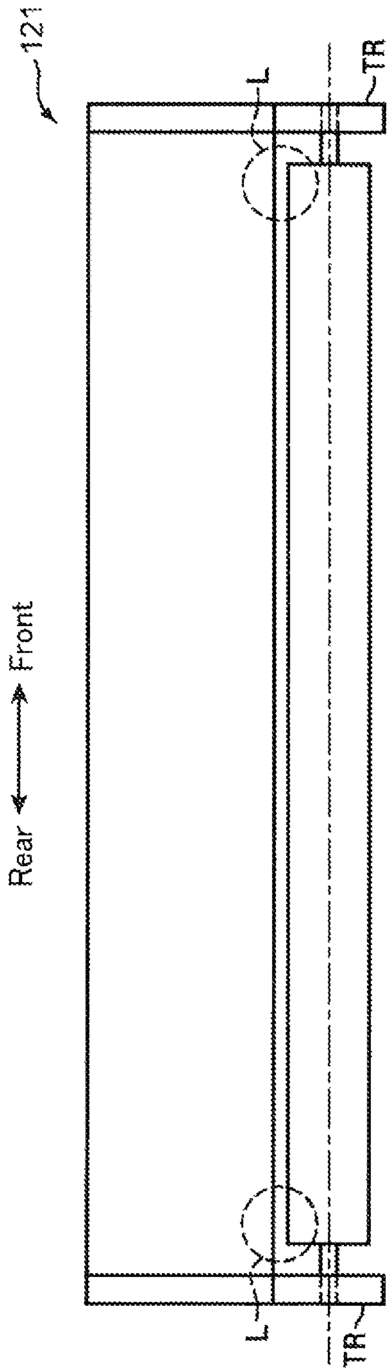


FIG. 3A

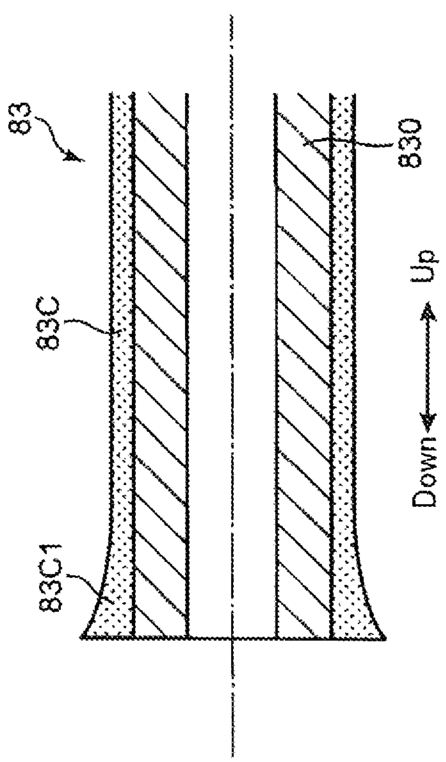
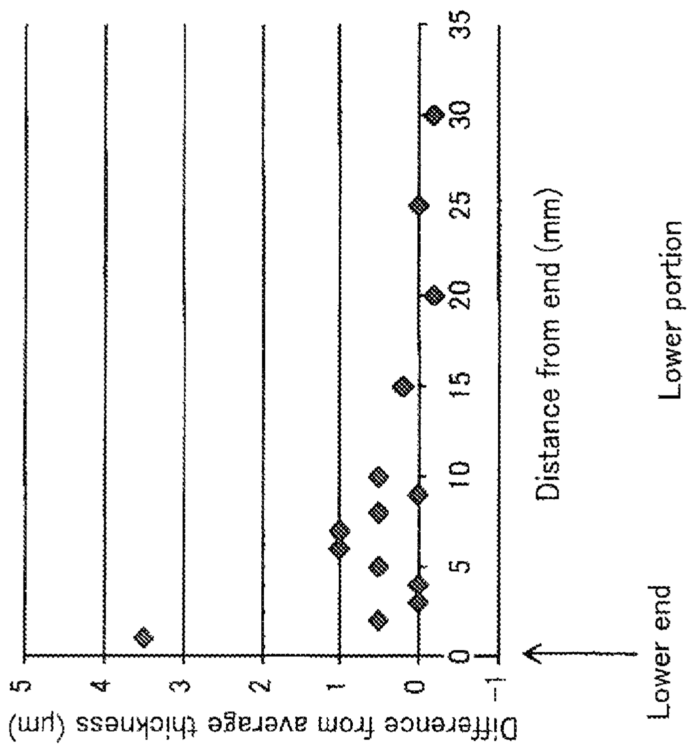


FIG. 3B


Difference from average thickness (μm)
5
4
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15
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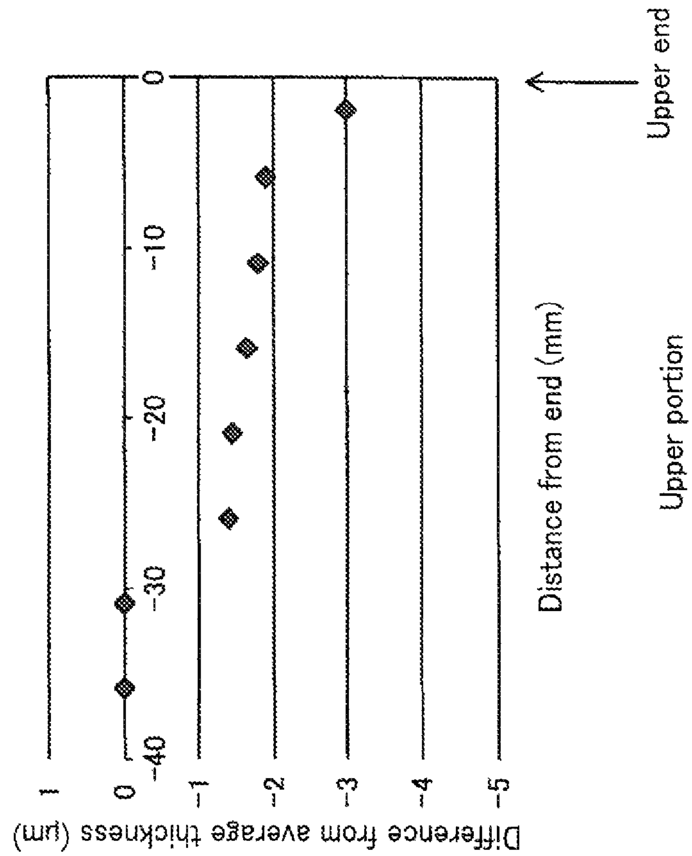
Distance from end (mm)
Lower end
Lower portion

FIG. 4A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Distance from end (mm)
Upper end
Upper portion

FIG. 4B

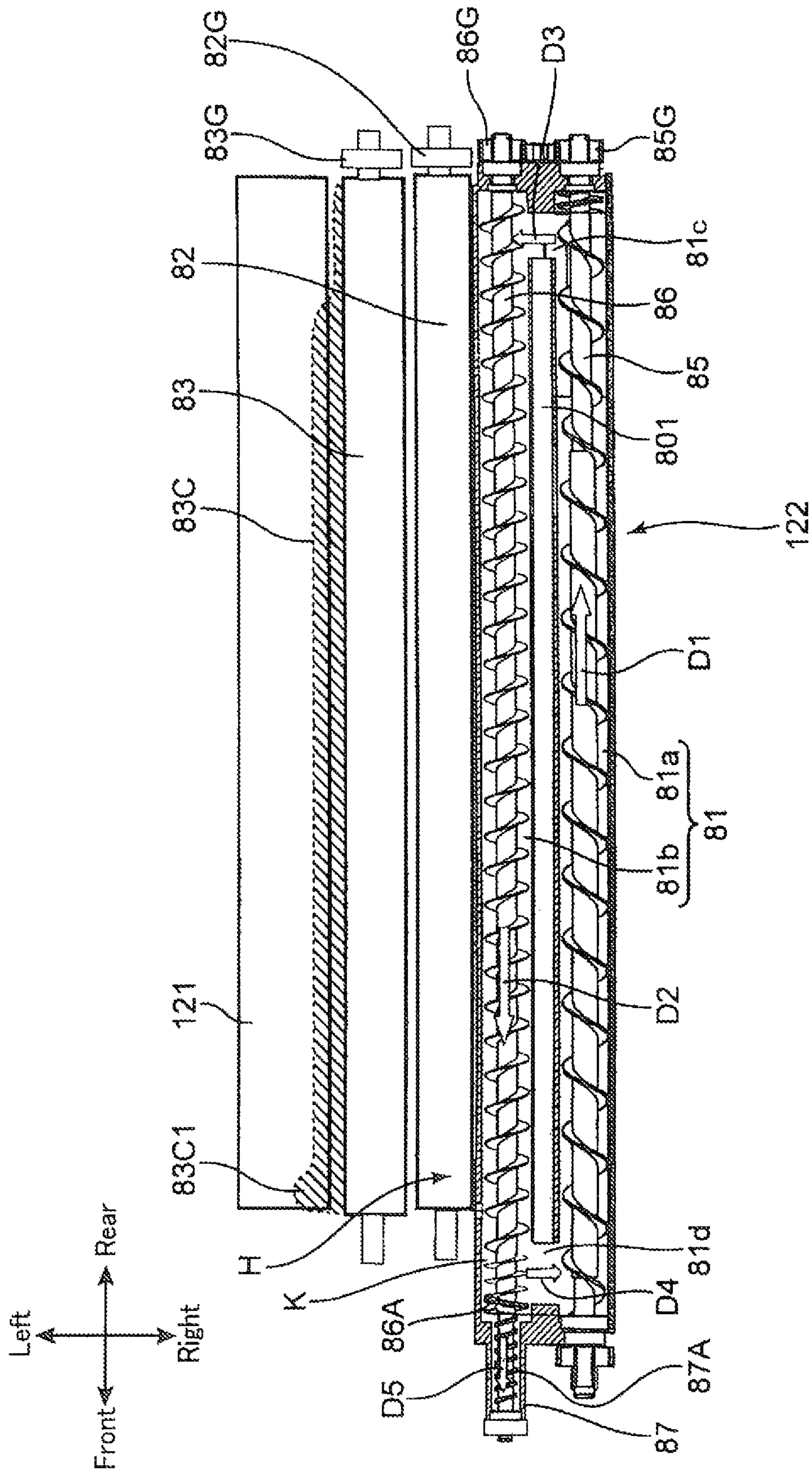
82G
83G
86G
D3
85G
82
81c
86
83
85
801
83C
122
D1
81a
81
81b
121
D2
83C1
Rear
81d
H
K
D4
Left
Right
86A
87A
D5
Front
87

FIG. 5

DEVELOPING DEVICE AND IMAGE FORMING APPARATUS INCLUDING THE SAME

INCORPORATION BY REFERENCE

The present application claims priority under 35 U.S.C. §119 to Japanese Patent Application No. 2014-082588, filed Apr. 14, 2014. The contents of this application are incorporated herein by reference in their entirety.

BACKGROUND

The present disclosure relates to a developing device and an image forming apparatus including the developing device.

Electrographic image forming apparatuses, such as copiers, printers, and facsimile machines, include a developing device that supplies toner to an electrostatic latent image formed on a photosensitive drum thereby to develop the electrostatic latent image. This forms a toner image on the photosensitive drum. The developing device includes a development roller (toner bearing member) rotatably disposed in a housing of the developing device. The development roller is spaced a predetermined gap away from the photosensitive drum and has a circumferential surface for bearing a developer, which at least contains toner. In one disclosure, a development roller is disposed opposite to the photosensitive drum. In another disclosure, a development roller is provided with a resin layer covering the surface of the development roller. In a yet another disclosure, a development roller is formed through a dipping process (dip method, dipping method) of dipping an element tube into a liquid resin in which a resin material has been dissolved.

SUMMARY

One aspect of the present disclosure provides a developing device that includes a housing, a toner bearing member, and a drive transmission section. The drive transmission section is disposed at one axial end of the toner bearing member and configured to transmit a rotational drive force to the toner bearing member. The toner bearing member has a circumferential surface for carrying toner thereon. The toner bearing member is axially rotatable in the housing and disposed a predetermined gap away from an image bearing member. The image bearing member has a circumferential surface on which an electrostatic latent image is formed. The toner bearing member includes a cylindrical base and a surface layer disposed over the base. The surface layer is formed through a dipping process of dipping the base into a dipping bath with the base directed axially vertically. The toner bearing member is mounted to the housing such that a lower axial end of the toner bearing member during the dipping process is an opposite axial end to the one axial end at which the drive transmission section is disposed.

Another aspect of the present disclosure provides an image forming apparatus that includes: the developing device according to the one aspect of the present disclosure described above; and the image bearing member having a circumferential surface on which an electrostatic latent image is formed and configured to receive supply of the toner from the toner bearing member.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** shows the structure of an image forming apparatus according to an embodiment of the present disclosure.

FIG. **2** is a side view showing the structure of a developing device according to the embodiment of the present disclosure.

FIG. **3**A shows the relative axial lengths of a photosensitive drum and a development roller both according to the embodiment; and FIG. **3**B is a cross-sectional view showing an end portion of the development roller, illustrating the thicknesses of a layer residing on the development roller.

FIGS. **4**A and **4**B are graphs each plotting the thickness distribution of the layer in an axial direction of the development roller according to the embodiment, FIG. **4**A directed to a portion of the development roller that is a lower portion during a dipping process and FIG. **4**B directed to a portion of the development roller that is an upper potion during the dipping process.

FIG. **5** is a plan view of the developing device according to the embodiment of the present disclosure.

DETAILED DESCRIPTION

The following explains an embodiment of the present disclosure with reference to the accompanying drawings. The present disclosure is applicable to electrographic image forming apparatuses, such as copiers, printers, facsimile machines, and multifunction peripherals combining such functions.

FIG. **1** shows the structure of an image forming apparatus **1** according to the embodiment of the present disclosure. The image forming apparatus **1** includes a main body **11**, an image forming section **12**, a fixing device **13**, a paper feed section **14**, a paper discharging section **15**, and a document reading section **16**.

The main body **11** is composed of a lower body **111**, an upper body **112**, and a connecting portion **113**. The upper body **112** is disposed above the lower body **111**. The connecting portion **113** is disposed between the upper body **112** and the lower body **111**, connecting the lower body **111** and the upper body **112** with the paper discharging section **15** secured therebetween. In FIG. **1**, the connecting portion **113** upstands from the top-left portion of the lower body **111**. The upper body **112** is supported on the top of the connecting portion **113**.

The image forming section **12**, the fixing device **13**, and the paper feed section **14** are disposed in the lower body **111**.

The image forming section **12** forms a toner image on a sheet of paper P fed from the paper feed section **14**. The image forming section **12** includes an unit **12**Y for yellow toner, a unit **12**M for magenta toner, a unit **12**C for cyan toner, a unit **12**Bk for black toner, an intermediate transfer belt **125**, a secondary transfer roller **196**, and a belt cleaner **198**. The units **12**Y, **12**M, **12**C, and **12**Bk are disposed in the stated order horizontally from the upstream to downstream in the moving direction of the intermediate transfer belt **125** (from the right to left in FIG. **1**). The units **12**Y, **12**M, **12**C, and **12**Bk each use toner of a corresponding color, namely yellow, magenta, cyan, or black. The intermediate transfer belt **125** is an endless belt entrained around a plurality of rollers including a drive roller **125**A and runs in a sub-scanning direction (the side-to-side direction in FIG. **1**) of an image forming process. The secondary transfer roller **196** is pressed against the outer circumferential surface of the intermediate transfer belt **125**.

The units **12**Y, **12**M, **12**C, and **12**Bk of the respective colors each include a photosensitive drum **121** (image bearing member), a developing device **122**, a toner cartridge (not shown), a charger **123**, and a drum cleaner **127**. Each developing device **122** supplies toner (developer) to the corresponding photosensitive drum **121**. Each toner cartridge contains toner of a corresponding color. Below the developing devices **122** adjacent to one another, an exposure device **124** is horizontally disposed for light exposure to the respective photosensitive drums **121**.

Each photosensitive drum **121** has a cylindrical shape and is rotated on its axis. The photosensitive drum **121** has a circumferential surface on which an electrostatic latent image is formed and a toner image developed with toner from the electrostatic latent image is carried. The photosensitive drum **121** according to the present embodiment is a known organic photoconductor (OPC). The photosensitive drum **121** has layers, such as a charge generating layer and a charge transport layer, on the surface. These layers are formed through a dipping process, in a manner similar to a development roller **83**, which will be described later.

Each developing device **122** supplies toner to an electrostatic latent image formed on the circumferential surface of the corresponding photosensitive drum **121** that is rotating in the direction of the arrow shown in FIG. **1**, causing the toner to adhere to the electrostatic latent image. This forms a toner image conforming to the electrostatic latent image on the circumferential surface of the photosensitive drum **121**. Each developing device **122** is replenished with toner from the corresponding toner cartridge.

Each charger **123** is disposed immediately under the corresponding photosensitive drum **121** and uniformly charges the circumferential surface of the photosensitive drum **121**.

The exposure device **124** is disposed below the chargers **123**. The exposure device **124** irradiates the charged circumferential surface of each photosensitive drum **121** with a laser beam in accordance with image data of the corresponding color, thereby forming an electrostatic latent image on the circumferential surface of the photosensitive drum **121**. The image data may be input from a computer or the like or acquired by the document reading section **16**. The exposure device **124** emits a laser beam to provide a predetermined amount of exposure so as to form a latent image at a predetermined potential on each photosensitive drum **121**. Each drum cleaner **127** is disposed on the left of the corresponding photosensitive drum **121** and removes residual toner from the circumferential surface of the photosensitive drum **121**.

The intermediate transfer belt **125** is an endless belt. More specifically, the intermediate transfer belt **125** is a conductive soft belt having a multilayered structure with a base layer, an elastic layer, and a coating layer. The intermediate transfer belt **125** is entrained around a plurality of rollers that are aligned substantially horizontally above the image forming section **12**. The rollers around which the intermediate transfer belt **125** is entrained include a drive roller **125**A and a driven roller **125**E. The drive roller **125**A is disposed near the fixing device **13** and drives the intermediate transfer belt **125** to rotate. The driven roller **125**E is horizontally spaced a predetermined distance away from the drive roller **125**A and is rotated by following the rotation of the intermediate transfer belt **125**. By a rotational drive force applied to the drive roller **125**A, the intermediate transfer belt **125** is driven to circulate clockwise in FIG. **1**.

The secondary transfer roller **196** is electrically connected to a section for applying a secondary transfer bias (not shown). A secondary transfer bias is applied between the secondary transfer roller **196** and the drive roller **125**A. The transfer bias causes transfer of the toner image formed on the intermediate transfer belt **125** to a sheet P conveyed from a pair of conveyance rollers **192**, which is disposed below. The belt cleaner **198** is disposed opposite to the driven roller **125**E across the intermediate transfer belt **125**.

The fixing device **13** includes a heating roller **132** and a pressure roller **134**. In the interior of the heating roller **132**, a conductive heating element, such as a halogen lamp, is provided as a heat source. The pressure roller **134** is disposed opposite to the heating roller **132**. The fixing device **13** applies heat from the heating roller **132** to a toner image that is transferred to a sheet P by the image forming section **12**, carrying out a fixing process of the toner image. The fixing process by the fixing device **13** is conducted while the sheet P passes through the fixing nip formed between the heating roller **132** and the pressure roller **134**. After the fixing process, the sheet P having a color image formed thereon is conveyed through a discharge conveyance path **194** extending from the upper portion of the fixing device **13** and discharged to an exit tray **151** disposed on the top of the main body **11**.

The paper feed section **14** includes a manual feed tray **141** and a paper feed cassette **142**. The paper feed cassette **142** is detachably disposed in the main body **11** at a position below the exposure device **124**. The paper feed cassette **142** contains a sheet stack P1, which is a stack of a plurality of sheets P. A pickup roller **143** is disposed above the paper feed cassette **142**. The pickup roller **143** feeds a topmost sheet P from the sheet stack P1 stored in the paper feed cassette **142** into a paper conveyance path **190**. In FIG. **1**, the manual feed tray **141** is disposed on the right-side wall of the main body **11** so as to be freely opened and closed. The manual feed tray **141** is used for manually feeding sheets P to the image forming section **12** one at a time.

The paper conveyance path **190** is disposed to extend vertically on the left of the image forming section **12**. The pair of conveyance rollers **192** is disposed at appropriate positions on the paper conveyance path **190**. The pair of conveyance roller **192** conveys a sheet P fed from the paper feed section **14** to a secondary transfer nip N formed between the secondary transfer roller **196** and the drive roller **125**A.

The paper discharging section **15** is provided between the lower body **111** and the upper body **112**. The paper discharging section **15** includes the exit tray **151** formed in the top surface of the lower body **111**. The exit tray **151** is for receiving a sheet P discharged after the fixing process of the sheet P by the fixing device **13**.

The document reading section **16** is disposed in the upper body **112**. The document reading section **16** includes contact glass **161**, a document holding cover **162**, and a scanning mechanism **163**. The contact glass **161** is for placing a document thereon. The document holding cover **162** is freely opened and closed to hold a document placed on the contact glass **161**. The scanning mechanism **163** scans the document placed on the contact glass **161** to read an image of the document. The scanning mechanism **163** includes an image sensor, such as charge coupled device (CCD) or a complementary metal oxide semiconductor (CMOS), to optically read an image of the document and generates image data representing the image. The main body **11** includes an image processing section (not shown) for creating an image for printing based on the image data.

Structure of Developing Device

The following explains the developing device **122** in detail. FIG. **2** is a side view showing the structure of the developing device **122**. FIG. **3**A shows the relative axial lengths of the photosensitive drum **121** and the development roller **83** both according to the present embodiment. FIG. **3**B is a cross-sectional view of an end portion of the development roller **83**, illustrating the thicknesses of a layer residing on the development roller **83**. FIGS. **4**A and **4**B are graphs each plotting the layer thickness distribution in an axial direction of the development roller **83**. More specifically, FIG. **4**A is a graph plotting the layer thickness distribution at a portion of the development roller **83** that is a lower portion during the dipping process, and FIG. **4**B is a graph plotting the layer thickness distribution at a portion of the development roller **83** that is an upper end during the dipping process. FIG. **5** is a plan view of the developing device **122** according to the present embodiment. For the purpose of explanation, FIG. **5** shows a magnetic roller **82** and the development roller **83** each at a position displaced leftward. The developing device **122** according to the present embodiment employs a touchdown developing method involving the use of the development roller **83** and the magnetic roller **82**. As shown in FIG. **2**. the developing device **122** includes a development housing **80** (housing) defining the interior space of the developing device **122**. The development housing **80** has a developer reservoir **81** (developer storing section) in which a developer is retained. The developer contains: non-magnetic toner that is chargeable to a predetermined polarity; and magnetic carrier. The development housing **80** houses therein the magnetic roller **82** (developer bearing member), the development roller **83** (toner bearing member), and a developer limiting blade **84** (layer-thickness limiting member). The magnetic roller **82** is disposed above the developer reservoir **81**. The development roller **83** is disposed opposite to the magnetic roller **82** at a position diagonally above the magnetic roller **82**. The developer limiting blade **84** is disposed opposite to the magnetic roller **82**. The developing device **122** additionally includes a driving section **962** and a developing bias applying section **88**.

As shown in FIGS. **2** and **5**, the developer reservoir **81** includes a first chamber **81***a* and a second chamber **81***b* extending in the longitudinal direction of the developing device **122** so as to be adjacent to each other. The second chamber **81***b* is disposed opposite to the magnetic roller **82**. The first chamber **81***a* and the second chamber **81***b* are partitioned from each other with a partition plate **801** extending integrally from the development housing **80** in the longitudinal direction. The first chamber **81***a* and the second chamber **81***b* are in communication through a first connecting portion **81***c* and a second connecting portion **81***d* disposed at the ends opposing in the longitudinal direction (axial ends) of the respective chambers **81***a* and **81***b*. The first chamber **81***a* and the second chamber **81***b* respectively accommodate a first screw feeder **85** and a second screw feeder **86** (conveyance member) each axially rotate to convey the developer while stirring. The first screw feeder **85** and the second screw feeder **86** are driven to rotate by the driving section **962**. The first screw feeder **85** and the second screw feeder **86** are set to rotate in the mutually opposite directions. With the above arrangement, the developer is circulated through the first chamber **81***a* and the second chamber **81***b* in a path indicated by the arrows D**1**, D**3**, D**2**, and D**4** shown in FIG. **5** while being stirred. The stirring of the developer in the manner described above mixes the toner and the carrier to charge the toner to, for example, a positive polarity. The first screw feeder **85** is provided with a first screw gear **85**G at the rear end, and the second screw feeder **86** is provided with a second screw gear **86**G at the rear end.

As shown in FIG. **2**, the magnetic roller **82** is rotatably disposed in the development housing **80** and extends in the longitudinal direction of the developing device **122** at a position opposite to the development roller **83**. The magnetic roller **82** is driven to rotate clockwise shown in FIG. **2**. The magnetic roller **82** is provided with a fixed magnet roll (fixed magnet) in its interior. The magnet roll has a plurality of polarities, namely a pump pole **821**, a limiting pole **822**, and a main pole **823**. The pump pole **821** is disposed opposite to the developer reservoir **81**, the limiting pole **822** is disposed opposite to the developer limiting blade **84**, and the main pole **823** is disposed opposite to the development roller **83**.

By the magnetic force of the pump pole **821**, the magnetic roller **82** magnetically pumps up (attracts) the developer from the developer reservoir **81** onto its circumferential surface **82**A. The magnetic roller **82** magnetically holds a layer of the attracted developer (magnetic brush layer) on the circumferential surface **82**A. The magnetic roller **82** then supplies toner to the development roller **83**. As the magnetic roller **82** rotates, the developer is conveyed toward the developer limiting blade **84**.

The developer limiting blade **84** is disposed opposite to the magnetic roller **82** at a position upstream from the development roller **83** in the rotation direction of the magnetic roller **82**. The developer limiting blade **84** limits the thickness of the developer accumulated on the circumferential surface **82**A of the magnetic roller **82**. The developer limiting blade **84** defines a limiting gap G of a predetermined size with the circumferential surface **82**A of the magnetic roller **82**. The arrangement described above ensures that the developer layer formed on the circumferential surface **82**A to have a uniform predetermined thickness.

The development roller **83** is disposed to extend in parallel to the magnetic roller **82** and driven to rotate clockwise shown in FIG. **2**. The development roller **83** is disposed opposite to the photosensitive drum **121** shown in FIG. **1**. The development roller **83** has a cylindrical shape and disposed in the development housing **80** so as to be axially rotatable. Throughout its rotation, the development roller **83** stays in contact with the developer layer held on the circumferential surface **82**A of the magnetic roller **82**. The development roller **83** receives toner form the developer layer held on the circumferential surface **82**A of the magnetic roller **82** and holds a layer of the received toner. The development roller **83** has a circumferential surface **83**A on which the toner layer is held. In the developing process, the development roller **83** supplies toner from the toner layer to the circumferential surface of the corresponding photosensitive drum **121**. As shown in FIG. **3**B, the development roller **83** according to the present embodiment includes a cylindrical sleeve **830** (base) and a resin coating layer **83**C (nylon coat, surface layer) formed on the circumferential surface of the sleeve **830**.

As shown in FIG. **2**, the development roller **83**, the magnetic roller **82**, the first screw feeder **85**, and the second screw feeder **86** are all driven to rotate by the driving section **962**. As shown in FIG. **5**, a roller gear **83**G (drive transmission section) is fixed at the rear end of the development roller **83**. In addition, an input gear **82**G is fixed at the rear end of the magnetic roller **82**. The driving section **962** (see FIG. **2**) is a motor that generates a rotational drive force. The driving section **962** is coupled to the input gear **82**G The rotational drive force input to the input gear **82**G is transmitted to the roller gear **83**G and the second screw gear **86**G The roller gear **83**G transmits the rotational drive force to the development roller **83**. The second screw gear **86**G transmits the rotational drive force to the second screw feeder **86**. The second screw gear **86**G is also coupled to the first screw gear **85**G The first screw gear **85**G transmits the rotational drive force to the first screw feeder **85**. Consequently, the rotational drive force generated by the driving section **962** rotates the development roller **83**, the magnetic roller **82**, the first screw feeder **85**, and the second screw feeder **86** in synchronism.

As shown in FIG. **2**, a gap S of a predetermined size is secured between the circumferential surface **83**A of the development roller **83** and the circumferential surface **82**A of the magnetic roller **82**. The gap S is set to be 0.3 mm, for example. The development roller **83** is disposed to face the photosensitive drum **121** (see FIG. **1**) through an opening formed in the development housing **80** and has a gap of a predetermined size between the circumferential surface **83**A and the circumferential surface of the photosensitive drum **121**. In the present embodiment, the gap is set to be 0.12 mm.

The developing bias applying section **88** applies a developing bias, which is generated by superimposing an alternating-current (AC) voltage on a direct-current (DC) voltage, to the magnetic roller **82** and the development roller **83**. An AC voltage is applied between the photosensitive drum **121** and the development roller **83** as well as between the development roller **83** and the magnetic roller **82**. As a consequence, toner is supplied from the magnetic roller **82** to the development roller **83** and subsequently from the development roller **83** to the photosensitive drum **121**. The development roller **83** therefore receives a higher AC voltage for causing the toner transfer, as compared with a known one-component or two-component developing device.

As shown in FIG. **5**, the developing device **122** additionally includes a reverse conveyance section **86**A (developer retaining section) and a developer discharging section **87**. The reverse conveyance section **86**A is a screw impeller coaxially fixed to the second screw feeder **86** at the front end of the second chamber **81***b*. The screw impeller constituting the reverse conveyance section **86**A is disposed to have a feeding direction that is reverse to the feeding direction of the screw impeller of the second screw feeder **86**. The reverse conveyance section **86**A is disposed opposite to the front end of the second connecting portion **81***d*. The reverse conveyance section **86**A rotates integrally with the second screw feeder **86** to push back the developer conveyed by the second screw feeder **86**, causing some of the developer to be retained there.

The developer discharging section **87** is in communication with the second chamber **81***b* at a position forward of the reverse conveyance section **86**A. The developer discharging section **87** includes a cylindrical wall defining an interior space and a discharge screw **87**A rotatable in the interior space. The discharge screw **87**A is a screw impeller coaxially fixed to the second screw feeder **86**. The discharge screw **87**A is disposed to have the same feeding direction as the screw impeller of the second screw feeder **86**. Some of the developer once retained by the reverse conveyance section **86**A passes over the reverse conveyance section **86**A to flow into the developer discharging section **87**. The developer flown into the developer discharging section **87** is conveyed forward by the discharge screw **87**A and discharged from an exit port not shown in the figures. As has been described above, the present embodiment employs a trickle technique for causing some of the developer to be discharged from the developing device **122**. To replenish the developing device **122** with carrier, the toner cartridge (not shown) may contain carrier in addition to toner or the developing device **122** may be provided with a carrier replenishing tank.

As shown in FIG. **3**A, the photosensitive drum **121** according to the present embodiment has an axial length that is longer than the axial length of the development roller **83**. Therefore, the axial ends of the development roller **83** correspond in position to regions L of the photosensitive drum **121**, the regions L being located axially inwardly of the axial ends of the photosensitive drum **121**. The development roller **83** is provided with a pair of tracking rollers TR one at each axial end. The tracking rollers TR abut against the end portions of the photosensitive drum **121**, thereby determining the gap between the development roller **83** and the photosensitive drum **121**. The development housing **80** is urged toward the photosensitive drum **121** by biasing springs (not shown). Consequently, the gap between the development roller **83** and the photosensitive drum **121** is stably maintained.

As show in FIG. **3**B, the sleeve **830** of the development roller **83** is made from aluminum. The coating layer **83**C of the development roller **83** is formed through a dipping process explained below. First, the outer circumferential surface of the sleeve **830** is anodized to form an anodized layer (oxidized layer) having a thickness of 10 μm. The presence of an oxidized layer on the sleeve **830** that is made from aluminum increases the adhesion strength of the coating layer **83**C to the base. Thus, detachment of the coating layer **83**C is restricted. Then, the surface of the sleeve **830**, that is, the surface of the anodized layer is heated at 120° C. for 10 minutes or longer. The heat treatment is conducted to intentionally cause cracking in the sleeve **830** so as to reduce or prevent cracking during the process of drying the coating layer **83**C. The duration of the heat treatment is determined in advance to be equal to or longer than the time taken for the drying process, for example. The heat treatment is conducted always at a constant temperature and for a constant duration. This ensures that all of sleeves **830** subjected to the heat treatment will have an approximately constant amount of cracking. Subsequently to the heat treatment described above, a process of forming the coating layer **83**C on the anodized layer is conducted. More specifically, a liquid mixture is prepared by mixing: an alcohol-soluble nylon resin as a binder resin; titanium oxide as a conducting material; 800 parts by mass of methanol as a dispersion medium; and zirconia beads measuring 1.0 mm in diameter. The mixing is carried out for about 48 hours by using a ball mill. The anodized sleeve **830** is dipped into the liquid mixture for a predetermined time period and removed from the liquid mixture. Then, the sleeve **830** is dried for 10 minutes in a high temperature environment of 130° C. Note that the sleeve **830** is dipped into the liquid mixture with the axial direction of the cylindrical shape directed vertically. Through the dipping process described above, the coating layer **83**C coating the sleeve **830** is formed to a thickness ranging from 2 μm to 11 μm. As described above, prior to the coating of the anodized layer with the coating layer **83**C, cracking is caused in the anodized layer by a heat treatment. This is effective to prevent the conductive material contained in the coating layer **83**C to be localized under the influence of convection caused in the coating layer **83**C during the process of drying the coating layer **83**C. Consequently, the conductive material is ensured to be uniformly dispersed in the resultant coating layer **83**C.

Yet, forming the coating layer **83**C through the dipping process as described above involves that the liquid mixture adhering on the surface of the sleeve **830** tends to flow down by gravity when the sleeve **830** is lifted up from the liquid mixture. As a consequence, the coating layer **83**C formed on the surface of the sleeve **830** is thicker at a portion closer to an axial end of the sleeve **830** that was the lower axial end during the dipping than at a portion corresponding to the axial center of the sleeve **830**. In particular, the coating layer **83**C tends to have a thicker portion **83C1** at a position corresponding to the lower axial end (the front end in FIG. **3**) of the sleeve **830**. In addition, the coating layer **83**C tends to have a thinner portion at a position closer to an axial end of the sleeve **830** that was the upper axial end during the dipping process than at a portion corresponding to the axial center of the sleeve **830**.

FIG. **4**A is a graph plotting the layer thickness distribution of the coating layer **83**C at the lower portion of the sleeve **830**. FIG. **4**B is a graph plotting the thickness distribution of the coating layer **83**C at the upper portion of the sleeve **830**. In each graph, the horizontal axis represents the distance from the corresponding end (upper or lower end) of the sleeve **830**, whereas the vertical axis represents the difference from the average thickness of the coating layer **83**C. More specifically, the vertical axis represents the thickness of the coating layer **83**C at the respective axial positions of the development roller **83**, by plotting the difference from the average thickness of the coating layer **83**C. As shown in FIGS. **4**A and **4**B, with respect to the upper portion of the coating layer **83**C, a thinner portion extends for a length (30 mm) that is longer than the length of a portion that is thicker than the average (15 mm) In addition, the thickness reduction (3 μm) of the coating layer **83**C at the upper portion is close to the value of the thickness increase (3.5 μm) of the coating layer **83**C at the lower portion.

FIG. **5** exaggerates the thickness distribution of the coating layer **83**C coating the development roller **83**. As described above, according to the present embodiment, the coating layer **83**C is formed by dipping the sleeve **830** into a dipping bath with the axial direction of the development roller **83** directed vertically. The development roller **83** is mounted to the development housing **80** such that the lower axial end of the development roller **83** at the time of the dipping is the front end that is opposite from the roller gear **83**G (from the rear end).

The development roller **83** is pressed at the rear end toward the photosensitive drum **121** due to the meshing of the gear teeth between the input gear **82**G and the roller gear **83**G that is caused upon transmission of the rotational drive force from the input gear **82**G to the roller gear **83**G. Thus, at the rear end portion of the development roller **83**, the gap between the development roller **83** and the photosensitive drum **121** is stably maintained by the pair of tracking rollers TR described above. At the front end portion of the development roller **83**, on the other hand, the development roller **83** may not be reliably positioned due to the absence of the pressing force produced by the input gear **82**G and the roller gear **83**G meshing with each other in a manner described above. The development roller **83** may wobble or may be off centered within predetermined tolerances. Under the influence by these factors, the gap between the development roller **83** and the photosensitive drum **121** tends to fluctuate at the front end portion of the development roller **83**. When the gap between the development roller **83** and the photosensitive drum **121** is larger at the front end portion of the development roller **83** than at the rear end portion, toner images formed on the photosensitive drum **121** suffer from reduction in image density or inconsistency in image density appearing at intervals corresponding to the rotation pitch of the development roller **83**.

According to the present embodiment, the coating layer **83**C is relatively thicker at a portion closer to an end that was the lower end of the development roller **83** during the dripping process, and the development roller **83** is mounted to the developing device **122** such that the relatively thicker portion of the coating layer **83**C is positioned toward the front of the developing device **122**. Therefore, by the difference in the thickness of the coating layer **83**C, the gap between the development roller **83** and the photosensitive drum photosensitive drum **121** is narrower in part, and the developing electric field at such a portion is maintained relatively strong. This can restrict the reduction or inconsistency in image density at the front end portion (opposite to the driving end) of the developing device **122**.

Note in addition that the present embodiment employs a touchdown developing method as described above. In the developing device **122**, a magnetic brush is formed from toner and carrier on the circumferential surface of the magnetic roller **82**. The strong abrasive force of the magnetic brush results in wear of the coating layer **83**C of the development roller **83**. The abrasive force of the magnetic brush fluctuates according to the concentration of the toner in the magnetic brush. When the concentration of the toner is low and thus the carrier surfaces tend to be exposed, the abrasive force of the magnetic brush increases to accelerate wear of the coating layer **83**C. As shown in FIG. **5**, the second screw feeder **86** gradually supplies the developer to the magnetic roller **82** while conveying the developer forward. In addition, as the toner on the development roller **83** is consumed, the developer with a low toner concentration is appropriately collected into the second chamber **81***b*. Consequently, the concentration of the toner in the second chamber **81***b* is gradually lower from the rear toward the front. Thus, the concentration of the toner in the developer carried on the magnetic roller **82** is relatively lower toward the front end of the magnetic roller **82**. Therefore, as explained above, the abrasive force of the magnetic brush on the magnetic roller **82** is greater in a specific region (region H shown in FIG. **5**). This phenomenon is particularly notable when the image forming apparatus **1** continuously prints images at a high coverage rate.

According to the present embodiment, the coating layer **83**C is relatively thicker at a portion closer to an end of the development roller **83** that was the lower end during the dipping process, and the development roller **83** is mounted to the developing device **122** such that the lower end of the coating layer **83**C is positioned toward the front of the developing device **122**. As a consequence, despite the strong abrasive force of the magnetic brush, the portion of the coating layer **83**C closer toward the front is restricted from becoming thinner than the portion closer toward the rear. In addition, the arrangement described above is effective to prevent detachment of the coating layer **83**C by a mechanical force applied by the magnetic brush. Note that, at the front end portion of the magnetic roller **82**, the concentration of the toner tends to be lower and thus the chargeability of the toner tends to be higher. As a result, the toner carried on the front end portion of the development roller **83** may be in sufficient to appropriately develop a latent image on the photosensitive drum **121**, which tends to cause reduction in the resulting image density. Yet, as described above, the gap between the photosensitive drum **121** and the development roller **83** is set to be partially narrower at a position closer to the front end of the development roller **83** which promotes the developing action and thus prevents the image density reduction.

The developing device **122** according to the present embodiment has the developer discharging section **87**. Components, carrier in particular, of the developer are gradually replaced while the carrier is held in the developer reservoir **81**, which increases the longevity of the developer. Consequently, the present embodiment ensures stable image formation over a long period of time. With reference to FIG. **5**, it is noted that the developer in the second chamber **81***b* has high fluidity in the downstream end portion and thus can be readily discharged. By the reverse conveyance section **86**A, some of the developer is retained to form accumulation K. Most of the accumulation K is conveyed through the second connecting portion **81***d* to the first chamber **81***a*. In addition, as described above, some of the developer passes over the reverse conveyance section **86**A and is discharged from the developer discharging section **87**.

The accumulation K formed in the downstream end portion of the second chamber **81***b* leads to an increase in the amount of the developer carried on the front end portion of the circumferential surface of the magnetic roller **82**. Consequently, the amount of the developer that is carried beyond the developer limiting blade **84** is greater at the front end portion than at the rear end portion. This leads to a further increase of the abrasive force of the magnetic brush. As has been described above, the development roller **83** is mounted such that the lower end during the dipping process is disposed toward the front of the developing device **122**. This restricts the coating layer **83**C from becoming thin even in the structure that the developer discharging section **87** is disposed at the downstream of the second chamber **81***b*.

The explanation given above is directed to the developing device **122** and the image forming apparatus **1** according to the embodiment of the present disclosure. However, the present disclosure is not limited to the specific embodiment, and various alterations including the following may be made.

(1) In the embodiment given above, the image forming apparatus **1** is explained as being a full color image forming apparatus, which should not be construed as a limitation. The image forming apparatus **1** may be a monochrome image forming apparatus that prints black and white images.

(2) In the embodiment above, the second screw feeder **86** conveys developer from the side closer to the roller gear **83**G, which should not be construed as a limitation. The second screw feeder **86** may convey the developer toward the side closer to the roller gear **83**G Alternatively, the second screw feeder **86** may convey the developer in a direction toward the thicker portion **83C1** (the lower end of the development roller **83** at the time of the dipping) irrespective of the disposition of the roller gear **83**G Similarly, the developer discharging section **87** may be disposed in accordance with the lower end of the development roller **83** at the time of the dipping, irrespective of the disposition of the roller gear **83**G.

EXAMPLES

Now, the following explains a preferred manner of the development roller **83** of the developing device by way of example. Examples given below were subjected to experiments in the following conditions.

Experimental Conditions

- Printing rate: 30 sheets/min
- Photosensitive drum **121**: OPC drum
- Peripheral speed of the photosensitive drum **121**: 180 mm/sec
- Development roller **83**: anodized surface treatment+nylon resin coating
- Peripheral speed of the development roller **83**: Ratio of 1.5 relative to the peripheral speed of the photosensitive drum **121** (the same rotation direction as the photosensitive drum **121**)
- Peripheral speed of magnetic roller: Ratio of 1.1 relative to the peripheral speed of the development roller **83** (the opposite rotation direction from the photosensitive drum **121**)
- Gap between the photosensitive drum **121** and the development roller **83**: 0.12 mm
- Gap between the magnetic roller **82** and the development roller **83** 0.3 mm
- Surface potential of the photosensitive drum **31**: +430 V (at background portion) and +100 V (at image portion)
- Developing bias applied to the development roller **83**: Frequency of AC voltage=3.7 kHz, Duty=27%, Vpp=1,500 V, and DC voltage=190 V
- Developing bias applied to the magnetic roller **82**: Frequency of AC voltage=3.7 kHz, Duty=73%, Vpp=650 V, and DC voltage=490 V
- Average size of toner particles: 6.8 μm (positively chargeable)

In Example 1, the development roller **83** was disposed such that the lower axial end during the dipping process was positioned toward the front of the developing device **122** (at a position away from the roller gear **83**G) as in the embodiment described above. In Comparative Example 1, the development roller **83** was disposed such that the lower axial end during the dipping process was positioned toward the rear of the developing device (at a position toward the roller gear **83**G). Example 1 and Comparative Example 1 were each subjected to a process of continuously producing 500K (500×1,000) prints of an image at a coverage rate of 3.8%. Table 1 shows changes in the thickness of the coating layer **83**C.

TABLE 1

			Start	100K Prints	200K Prints	300K Prints	400K Prints	500K Prints
Example 1	Layer Thickness (μm)	Toward Driving Side	4.0	3.8	3.6	3.5	3.4	3.3
		Away From Driving Side	10.0	8.2	6.4	4.7	6.6	5.9
	State of Density Inconsistency		Good	Good	Good	Good	Good	Good
Comparative Example 1	Layer Thickness (μm)	Toward Driving Side	10.0	9.0	8.2	7.4	6.7	6.0
		Away From Driving Side	4.0	3.7	3.4	3.1	2.8	2.5
	State of Density Inconsistency		Acceptable	Acceptable	Poor	Poor	Poor	Poor

As shown in Table 1, the development roller **83** of Example 1 was disposed such that the lower axial end (initial layer thickness of 10 μm) was positioned away from the driving side where the roller gear **83**G was disposed. As a result, the thickness of the coating layer **83**C was not below 3 μm upon completion of the process of producing 500K prints. Therefore, stable image forming operation was maintained. On the other hand, the development roller **83** of Comparative Example 1 was disposed such that the upper axial end (initial thickness of 4 μm) was positioned away from the driving side where the roller gear **83**G was disposed. As a result, at the time of producing 200K prints and onward, density inconsistency appeared at the intervals corresponding to the rotation pitch of the development roller **83**.

In Example 2, in the same manner as the embodiment described above, the aluminum sleeve **830** (base) having a diameter of 20 mm was anodized and then the coating layer **83**C was formed to an average thickness of 6 μm on the sleeve **830**. The thickness of the coating layer **83**C was 10 μm at a portion corresponding to the lower axial end of the development roller **83** during the dipping process. The coating layer

83C was formed from a nylon resin containing 100 parts by mass of titanium oxide dispersed therein. In Comparative Example 2, the aluminum sleeve **830** (base) having a diameter of 20 mm was anodized and then a coating layer was formed by spraying to an average thickness of 6 μm on the sleeve **830**. The coating layer of Comparative Example 2 was formed from a urethane resin containing 100 parts by mass of titanium oxide and 5 parts by mass of carbon black dispersed therein. Example 2 and Comparative Example 2 were both subjected to a process of continuously producing 100K (100×1,000) prints of an image at coverage rate of 50%. Table 2 shows changes in the thickness of the respective coating layers.

TABLE 2

			Start	100K Prints	200K Prints	300K Prints	400K Prints	500K Prints
Example 2	Layer Thickness (μm)	Toward Driving Side	4.0	3.8	3.6	3.4	3.2	3.0
		Away From Driving Side	10.0	9.0	8.0	7.0	6.0	5.0
Comparative Example 2	Layer Thickness (μm)	Toward Driving Side	6.0	5.4	4.8	4.2	3.6	3.0
		Away From Driving Side	6.0	4.0	2.0	1.0	0.0	0.0

As shown in Table 2, the thickness of the coating layer **83**C of Example 2 was not below 3 μm upon completion of continuous 100K prints of an image at a high coverage rate of 50%. Consequently, favorable images were stably formed. On the other hand, the thickness of the coating layer of Comparative Example 2 formed by spraying was reduced at the end portion away from the driving side and worn out by the time of completion of 80K prints. Different from Comparative Example 2, in addition, the coating layer of Example 2 contained titanium oxide as the sole conducting material, which improved the strength of the resulting coating layer and the abrasion amount of the coating layer.

What is claimed is:

1. A developing device comprising:

a housing;

a toner bearing member having a circumferential surface for carrying toner thereon, the toner bearing member being axially rotatable in the housing and disposed a predetermined gap away from an image bearing member, the image bearing member having a circumferential surface on which an electrostatic latent image is formed; and

a drive transmission section disposed at one axial end of the toner bearing member and configured to transmit a rotational drive force to the toner bearing member, wherein

the toner bearing member includes a cylindrical base and a surface layer disposed over the base,

the surface layer is formed through a dipping process of dipping the base into a dipping bath with the base directed axially vertically,

the toner bearing member is mounted to the housing such that a lower axial end of the toner bearing member during the dipping process is an opposite axial end to the one axial end at which the drive transmission section is disposed, and

the surface layer of the toner bearing member is made from alcohol-soluble nylon only including titanium oxide dispersed therein.

2. The developing device according to claim **1**, further comprising:

a developer bearing member having a circumferential surface for carrying developer that contains toner and carrier and supplying the toner to the toner bearing member, the developer bearing member being axially rotatable in the housing and disposed opposite to the toner bearing member;

a developer storing section configured to store developer and disposed in the housing at a position opposite to the developer bearing member; and

a conveyance member disposed in the developer storing section so as to be axially rotatable, the conveyance member being configured to convey the developer in a direction from a side corresponding to the one axial end of the toner bearing member to a side corresponding to the opposite axial end of the toner bearing member and to supply the developer to the developer bearing member.

3. The developing device according to claim **2**, further comprising:

a layer-thickness limiting member disposed opposite to the developer bearing member and configured to limit a thickness of the developer carried on the developer bearing member;

a developer retaining section disposed at an end of the developer storing section, the end being on the side corresponding to the one axial end of the toner bearing member, the developer retaining section being configured to cause some of the developer to be retained; and

a developer discharging section configured to discharge some of the developer retained by the developer retaining section from the housing.

4. The developing device according to claim **1**, wherein

the base is made from aluminum,

the toner bearing member further includes an oxide layer disposed over a surface of the base, and

the surface layer is disposed over the oxide layer.

5. An image forming apparatus comprising:

the developing device according to claim **1**; and

the image bearing member having a circumferential surface on which an electrostatic latent image is formed and configured to receive supply of the toner from the toner bearing member.

6. The image forming apparatus according to claim **5**, further comprising

a pair of tracking rollers configured to determine the gap between the toner bearing member and the image bearing member.

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